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TRAC-P1A PREDICTIONS OF THE BATTELLE-FRANKFURT TOP BLOWDOWN TEST*

by

L. Neymotin
Department of Nuclear Energy
Brookhaven National Laboratory
Upton, New York 11973

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A top blowdown vessel experiment[1] carried out in West Germany (Battelle Institute at Frankfurt) has been selected as part of the independent assessment of TRAC-P1A[2]. The experiment provides the data necessary for evaluating the code's capabilities in predicting single- and two-phase choked flow through a nozzle as well as nonequilibrium two-phase flow in a vertical pipe.

The test section (Figure 1a) is a vessel of 0.78 m in I.D. and 11 m in height, and is supplied with a rod bundle heater to maintain the chosen thermodynamic conditions before the blowdown starts. A discharge nozzle of 0.143 m in I.D. is located at the sidewall of the vessel near the top. The nozzle is closed by a rupture disc which can be destroyed electrically. A diaphragm of .064 m in diameter has been installed close to the disc to simulate the rupture area.

Initially the vessel was filled with subcooled water up to a level of about the 7 m from the bottom. After the appropriate thermodynamic conditions inside the vessel were achieved (which in this particular test were supposed to be as follows: T_ℓ = 285°K and $P_{top} \approx$ 70.6 bar) the heater was turned off and the blowdown was initiated. At the beginning, pure steam was discharged through the nozzle. Later, the flow regime changed to a two-phase regime when the mixture level reached the nozzle.

Several pressure taps and thermocouples were placed at different vessel levels as well as in the nozzle to record the transient.

The modelling has been performed using TRAC's "TEE" component (Figure 1b) with two zero-flow "FILLS" at the TEE's top and bottom and with a pressure boundary condition at the free end of the secondary pipe accomplished by the "BREAK." In total, 120 nodes for the vessel (primary TEE pipe) and 10 for the discharge tube (secondary TEE pipe) were employed. The effect of the heater inside the vessel is taken into account by decreasing the flow area by 22 percent and the hydraulic diameter by approximately 10 times, compared to those for the vessel without the heater. The computations were done with the fully implicit option and required approximately two minutes on the CDC-7600 to cover the first three seconds of the blowdown.

Figure 2 shows the void, pressure, and temperature time history at the level of 6.35 m from the bottom (Curves a). Unfortunately the temperatures have been measured with some kind of regular error and could not be used for comparisons (the temperature values seen in the figure would imply that the liquid at that level is subcooled during the whole blowdown). The pressure comparison looks well with an exception between t = 0.15 and 0.75 seconds where it is overpredicted by about 5 percent, apparently due to overprediction of the computed vapor generation rate. In addition, TRAC does not predict the slight pressure rising taking place in the experiment from the time of about 2.3 seconds on after the two-phase mixture reaches the discharge nozzle. This rising can be explained by considering the jump in the amount of vapor leaving the vessel when the nozzle flow becomes two-phase. Figure 3 (Curves a) presents the mass flow rate and mixture level data. The area between the two-mixture level curves corresponds to the two-phase region where the sharp jump in voids occurs between a unity and a value of the bulk void fraction in the two-phase mixture. It is seen that TRAC overpredicts choked mass flow rate for both pure vapor and two-phase mixture flows. It should be noted, however, that the choked vapor flow rate predicted by TRAC matches very well the theoretically evaluated value which might be considered as an indication of some of the problems with the mass flow rate measurements in the experiment.

The calculated mixture level reaches the nozzle more quickly than in the experiment that could be caused by the present slip correlations implemented in TRAC. Assuming that the slip has been underestimated, a number of runs were made using different factors greater than unity in the expression for the relative velocity V_r. The factor value of about 1.25 has been determined as the best fitting one. Corresponding results obtained with the modified TRAC's version are shown in Figures 2 and 3 as dashed curves. It is clearly seen to what extent the change in the slip modifies the time history of the two-phase boundary. It is to be pointed out that the flow which is being considered corresponds to very low mass flux, and the conclusion drawn from this result might have restricted application and meaning. As was expected, this boundary rises up slower because the vapor moving upwards entrains less water than before (this causes the slight decreasing in the voids seen in Figure 2). The last TRAC result worth mentioning is the void in the discharge nozzle which was varied from 0.74 to 0.78 after the two-phase mixture had reached the nozzle level.

Because of possible inaccuracies in the temperatures measurements, another computer run was performed to determine the sensitivity of the blowdown characteristics to variations in the initial water temperature. Unlike the previous runs with constant initial water temperature everywhere in the vessel (285°C), the following temperature distribution has been chosen: from the bottom up to 3.75m--280°C; up to 6.35m--283°C; up to 7.07m--285°C. These temperatures were selected from the temperature vs. time plots for different levels at the time equal zero. It is seen from the results obtained at this time (Figures 2 and 3, Curves b) that the mixture level time history is more reasonable than the original run and is similar to the one obtained by interfering in the TRAC's "slip" subroutine. On the other hand, the pressure in the vessel appears to be underpredicted.

All of this emphasizes the importance of knowing accurately the measured temperature fields in the vessel (in addition to the pressure) in order to utilize the data in TRAC assessment.

Based on the tests analyzed to date, TRAC performs quite well for the Battelle top blowdown test and correctly predicts the sequence of the events.

REFERENCES

1. B. Holzer, T. Kanzleiter, F. Stenhoff, Battelle Institute, Frankfurt (Main), February 1977.

2. "TRAC-P1A: An Advanced Best-Estimate Comoputer Program for PWR LOCA Analysis," Los Alamos Scientific Laboratory Report, LA-7777-MS, Vol-1 (NUREG/CR-0665), May 1979.

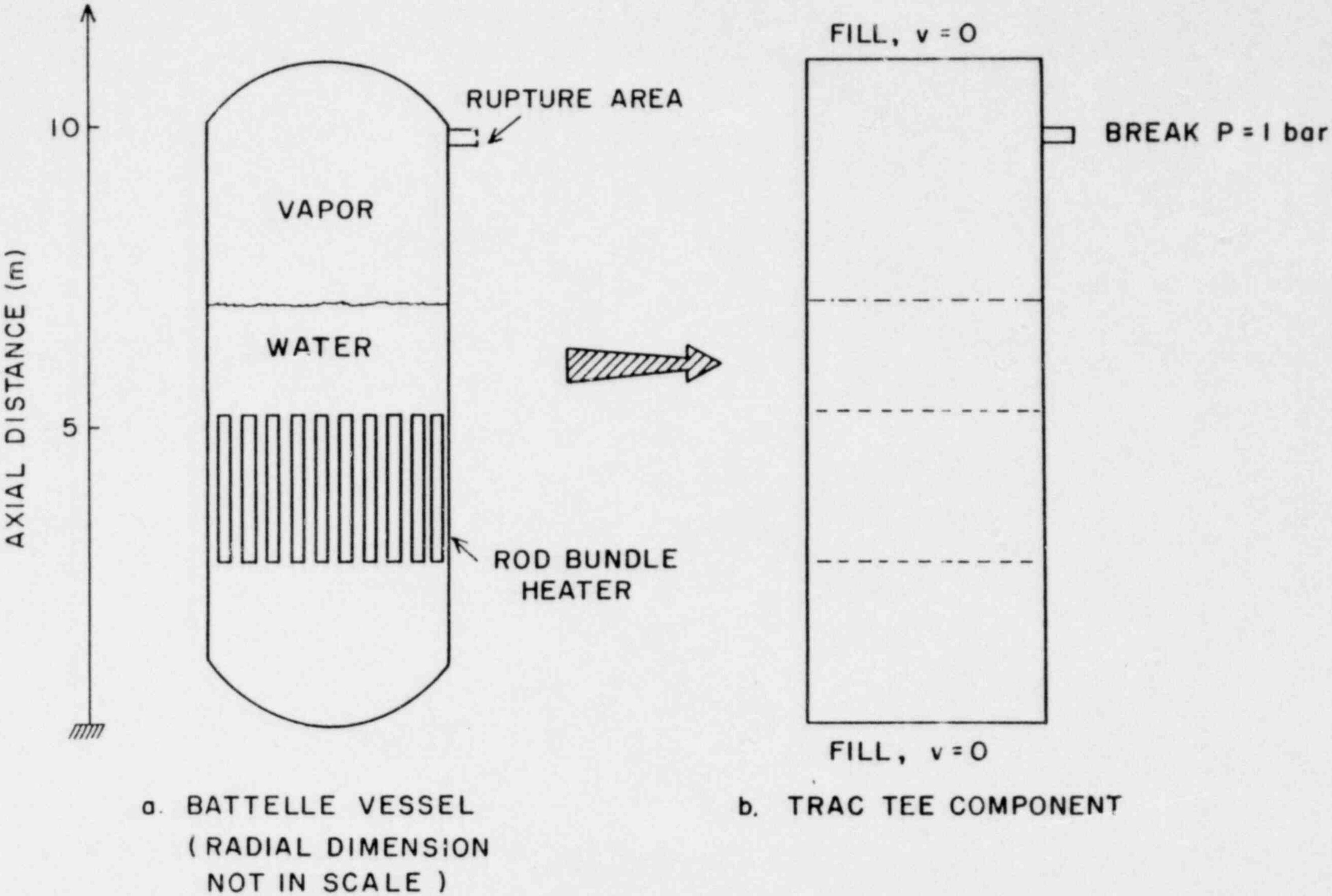

Figure 1. Battelle Vessel Schematic

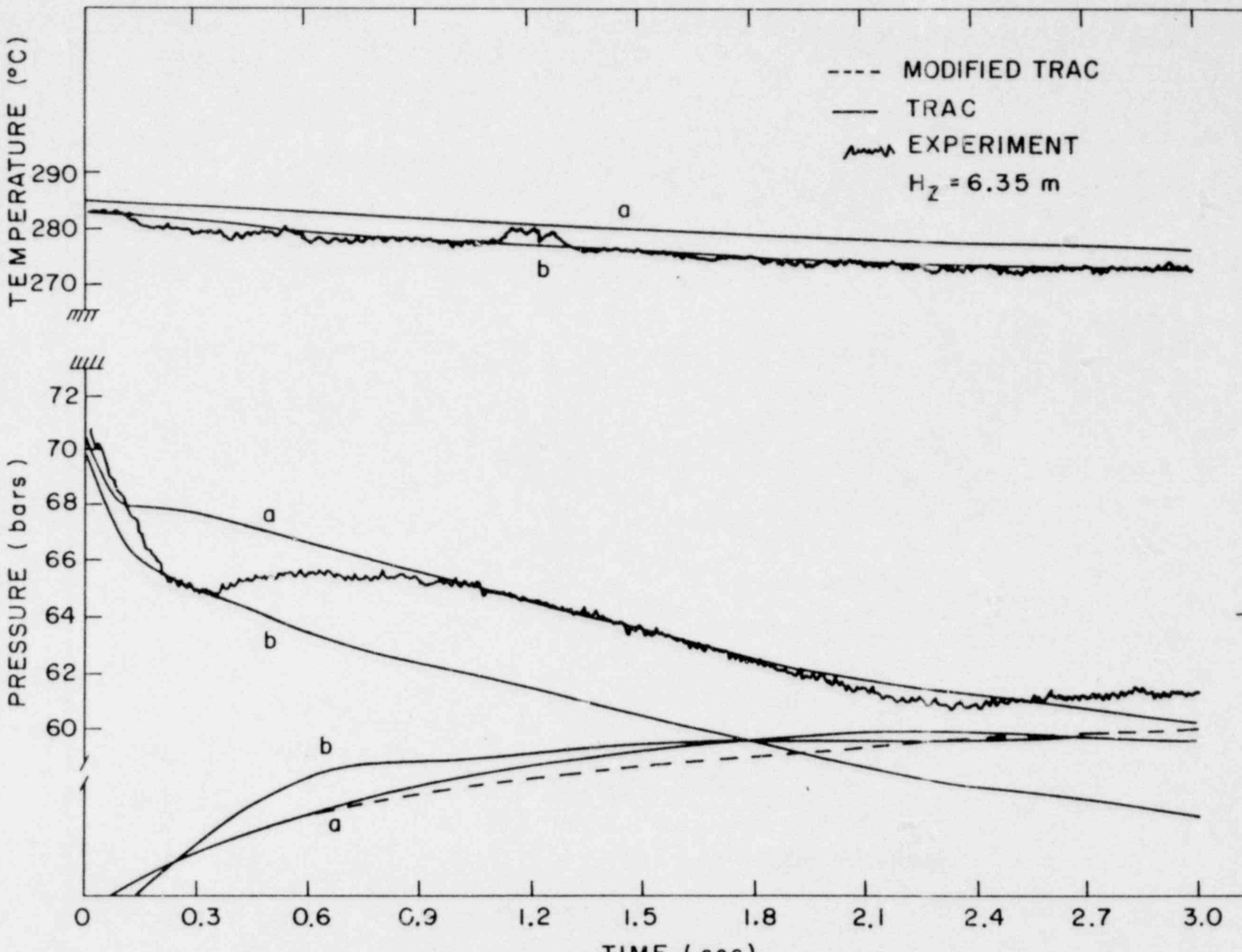

Figure 2. Temperature, pressure, and voids (lowest set of curves) time history

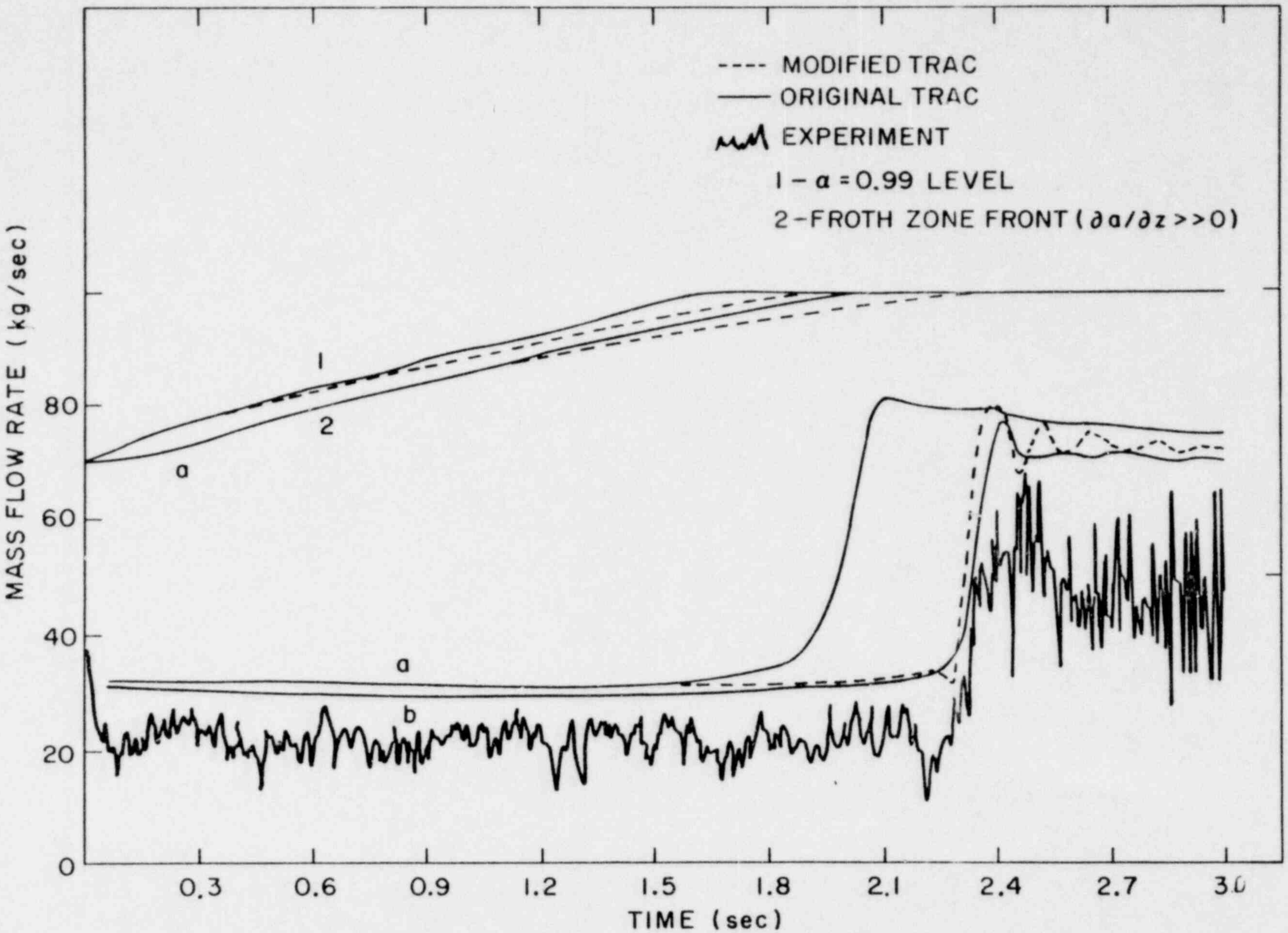

Figure 3. Mass flow rate and mixture level time history